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REPORT

SATELLITE BROADCASTING: the feasibility of adding a p.s.k. subcarrier sound signal to a f.m. television signal

N.H.C. Gilchrist, B.Sc., C.Eng., M.I.E.E.

Research Department, Engineering Division
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SATELLITE BROADCASTING: THE FEASIBILITY OF ADDING A PSK SUBCARRIER SOUND SIGNAL TO A FM TELEVISION SIGNAL

N.H.C. Gilchrist, B.Sc., C.Eng., M.I.E.E.

Summary

This Report describes experimental work which was carried out to determine whether a four-phase, phase-shift keyed (p.s.k.) sound subcarrier signal could be added to the baseband of a frequency-modulated (f.m.) television signal of the type currently proposed in Europe for satellite broadcasting, either instead of, or in addition to, the recommended f.m. sound subcarrier signal.

As a result of this work, it was found that while a four-phase p.s.k. sound signal could replace the f.m. sound subcarrier signal, it could not be used additionally without visible disturbance to the picture. Although p.s.k. would have the advantage of enabling two independent high-quality sound programmes to be radiated, the removal of the f.m. signal would mean a loss of any compatibility with receiver sound demodulation circuits used for reception in normal television broadcasting.

Issued under the authority of

P. Rainger

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION

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1. Introduction

Sub-Group K3 of the European Broadcasting Union have recommended* that television transmissions for direct broadcasting from satellites should be frequency-modulated with a deviation of 13 MHz peak-to-peak for a 1-Volt video signal, after CCIR pre-emphasis,[1] plus a deviation of ±2·8 MHz peak by a f.m. sound subcarrier at or near 6 MHz. It was intended that this subcarrier should carry the sound signal (monophonic) normally associated with the television programme. There is, however, considerable interest in Europe for a two-channel sound system which could provide either two independent sound signals, to meet dual-language requirements, or a high-quality two-channel stereo signal. The use of a second f.m. subcarrier at, say, 6·242 MHz, would entail restriction of subcarrier deviation to such an extent that neither sound channel would have a satisfactory signal-to-noise ratio. A four-phase p.s.k. sub-

* Recommendation of the meeting of EBU Sub-Group K3 held during 7th–9th February 1973, and reported in EBU Technical Review, April 1973, p. 106.

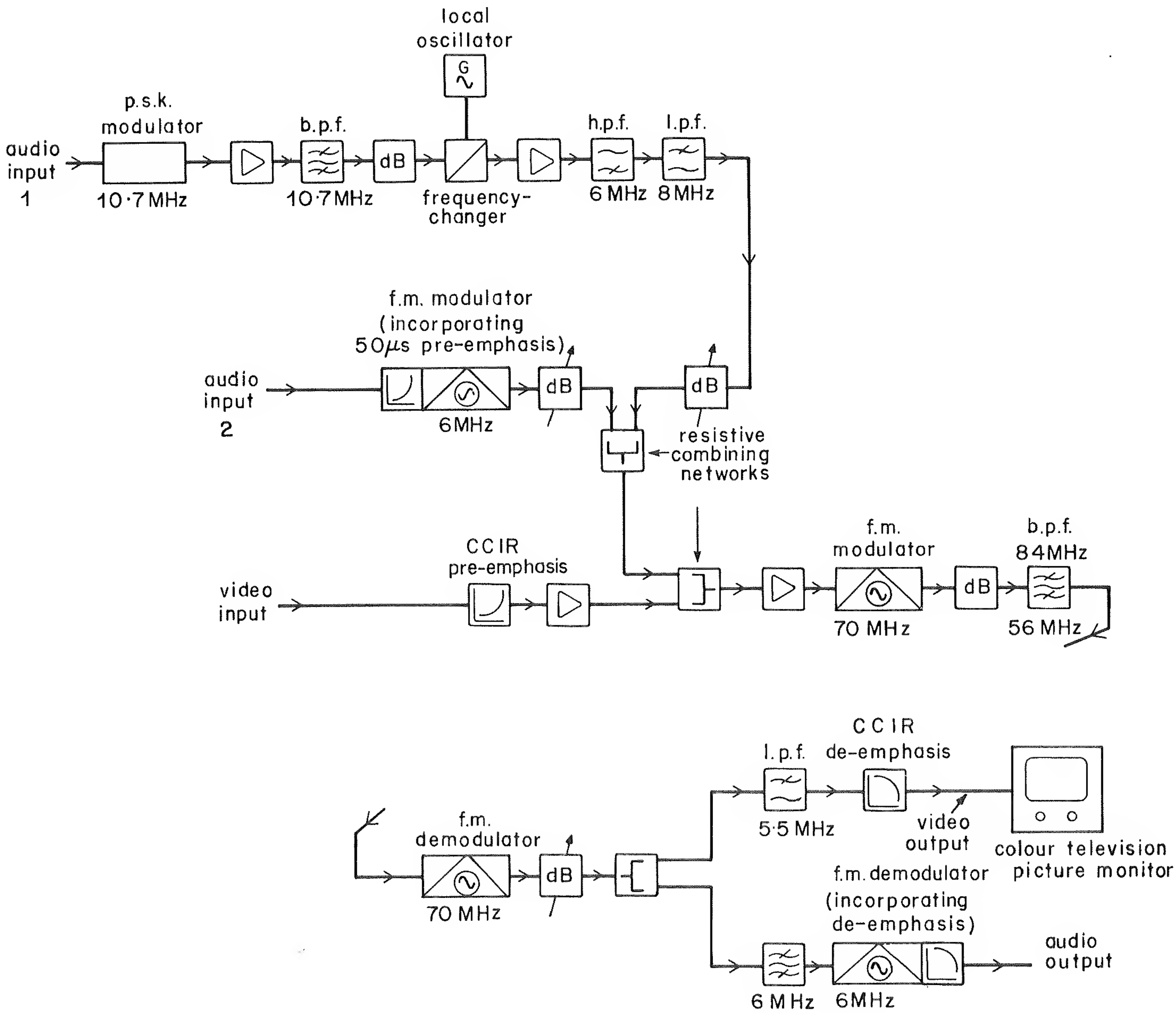

Fig. 1 - Experimental arrangement

carrier, carrying digitally coded sound signals, might be more attractive since it could provide either type of service, as the two channels of information would not be subject to cross-talk (unlike f.m. multiplex systems).

The work described in this Report was carried out in order to determine the level at which a p.s.k. subcarrier signal could be added to the video signal, either on its own or in addition to a f.m. subcarrier signal, without causing unacceptable impairment to the received picture, and hence whether a p.s.k. subcarrier would be suitable for a two-channel sound service accompanying a television programme.

2. Experimental arrangement

The experimental arrangement is shown in the block schematic diagram of Fig. 1. The p.s.k. signal was generated by an available experimental four-phase modulator operating at 10·7 MHz. The keying rate was 326 kHz, corresponding to a transmitted bit rate of 652 kbit/s. Its bandwidth was limited by a 10·7 MHz bandpass filter so that the spectrum of the p.s.k. signal was shaped to produce demodulated signal pulses of the 'raised-cosine' form. In a practical system, it is likely that the filtering would be divided between the transmitter and the receiver, part of the spectral shaping occurring in each of the two filters. Only one filter, which performed all the shaping, was available for these tests.

After filtering, the p.s.k. signal was converted to the required frequency and added to the (pre-emphasised) video and f.m. sound signals. An attenuator was provided so that the p.s.k. signal could be adjusted in level relative to that of the video and f.m. sound signals. The resulting composite television signal was used to frequency-modulate a 70 MHz carrier.

As a result of previous work,[2] EBU Sub-Group K3 have recommended that receivers for satellite direct television broadcasts should incorporate a 4-section bandpass filter having 27 MHz bandwidth. Accordingly, the signal was fed to a filter of this type, followed by a demodulator for the video and f.m. sound signals. No provision was available for demodulating the p.s.k. signal; the work was restricted to a determination of the levels at which interference from the p.s.k. signal became visible on the received picture.

3. Description of tests

3.1. Preliminary tests

It was apparent from the outset that when the level of p.s.k. signal was raised sufficiently to produce just-perceptible interference on the quiet f.m. subcarrier sound channel, there was already quite severe interference on the television picture. In subsequent tests, where the f.m. subcarrier sound signal was retained (i.e. where the p.s.k. signal was used in addition to the f.m. sound signal), attention was therefore confined to assessing the effects of the p.s.k. signal on the picture.

When using the p.s.k. signal together with the 6 MHz f.m. sound signal, very complex beat patterns could be seen on the picture even with the injection level of the p.s.k. signal at a very low value. With a p.s.k. subcarrier frequency of 7 MHz, the level of the p.s.k. signal needed to be at least 15 dB lower than that of the 6 MHz f.m. subcarrier in order to give a picture which was judged to be acceptable. Using a selection of still pictures and colour bars, attempts to reduce the visibility of patterns, which were most severe in areas of highly saturated colour, by offsetting the frequency of the p.s.k. subcarrier, met with little success because of the multiplicity of different interference products which were present simultaneously. Patterning was most objectionable when the p.s.k. and the f.m. subcarriers were both unmodulated.

A test in which the p.s.k. subcarrier frequency was reduced to 6·5 MHz gave similar results; the injection level of the p.s.k. signal needed to be reduced by a further 4 dB (i.e. to 19 dB below the level of the f.m. subcarrier) for an acceptable picture.

A theoretical estimate of the p.s.k. subcarrier level required for a satisfactory p.s.k. signal may be based upon an error rate requirement not exceeding 1 in 10^4 for a minimum carrier-to-noise ratio of 10 dB in a 27 MHz band at the input to the receiver f.m. demodulator. Allowing for a 30% loss of data eye-height in transmission, a p.s.k. subcarrier channel with a bandwidth of 330 kHz would require a minimum signal-to-noise ratio (r.m.s. signal to r.m.s. noise) of 14·4 dB. In order to achieve this the 7 MHz p.s.k. subcarrier would have to be at a level not less than −4 dB relative to the 6 MHz f.m. sound subcarrier. At this level, intermodulation between the f.m. and p.s.k. subcarriers would cause unacceptable interference to the received picture.

During the tests described so far, the level of the f.m. subcarrier at 6 MHz was kept constant at ±2·8 MHz peak deviation of the main carrier (the value recommended by the EBU). Any significant reduction of the f.m. subcarrier level would be likely to degrade the f.m. sound signal received at the limits of the service area. It appeared, however, that it would be necessary to reduce the f.m. subcarrier level by at least 6 dB (i.e. to ±1·4 MHz deviation of the main carrier) if the p.s.k. subcarrier were to be added to the vision plus f.m. sound signal without producing unacceptable impairment to the pictures. Subjective tests were therefore conducted, first with the f.m. subcarrier level reduced by 6 dB and second with the f.m. subcarrier completely removed.

Preliminary tests conducted without the f.m. subcarrier showed that interference to the picture was greatest in areas of saturated colour, as before, but now with the p.s.k. subcarrier modulated. A slight advantage was obtained by selecting an optimum frequency of 5·9996 MHz (within a tolerance of ±400 Hz) for the p.s.k. subcarrier. This is the same as the nominal rest frequency of the 6 MHz f.m. subcarrier and corresponds to the intercarrier frequency of the present UK television standard.

3.2. Subjective tests with both f.m. and p.s.k. subcarriers

Subjective viewing tests were conducted on a system incorporating a 6 MHz f.m. subcarrier, at a level corresponding to ±1·4 MHz deviation of the main carrier (i.e. 6 dB below that recommended by the EBU) plus a 7 MHz p.s.k. subcarrier which was varied in level over a wide range (from −10 dB to +10 dB relative to ±2·8 MHz deviation of the main carrier). The observers (five technical staff) sat at a distance of about six times picture height from the television screen, which was adjusted to give a peak white luminance of about 90 candela/m^2. The ambient illumination at the screen was about 7·5 lux. The f.m. subcarrier was unmodulated for all the tests, but the p.s.k. subcarrier was modulated by a pseudo-random sequence of digits for some tests, and unmodulated for others. The test pictures alternated between 100% colour bars, and the slide 'girl wearing a headscarf'.

The results are shown in Fig. 2. If a mean grade of 1½ on the 6-point scale* is taken as an acceptable level of picture impairment (i.e. 50% of the observers award grade 1, 50% award grade 2) it will be apparent that, even with the very much reduced level of f.m. sound subcarrier, the addition of a p.s.k. sound signal (for which the deviation would need to be at least −4 dB relative to ±2·8 MHz) would not be acceptable.

Attempts to improve system linearity by partly equalising the group-delay characteristics of the 70 MHz bandpass filter (see Fig. 1) produced only a small improvement — insufficient to alter materially the above conclusion.

3.3. Subjective tests with a p.s.k. subcarrier in place of the f.m. subcarrier

Subjective tests were conducted, as before, to establish the maximum level at which a p.s.k. subcarrier could be added to the video signal without causing an appreciable impairment to the pictures. The subcarrier frequency was set to an optimum frequency (5·9996 MHz ± 400 Hz — see Section 3.1), and it was, as before, modulated for some of the tests and unmodulated for others. The same slide and colour bars were also used for the picture material.

The results of the tests, given in Fig. 3, show that the most critical condition occurred when the picture consisted of colour bars, and the p.s.k. subcarrier was modulated. If an impairment level corresponding to grade 1½ is taken as acceptable it will be seen that the p.s.k. subcarrier may be added to the video signal at a level of −1 dB relative to ±2·8 MHz deviation of the main carrier without introducing unacceptable impairment into the picture. As shown in Section 3.1, this should provide an adequate sound service.

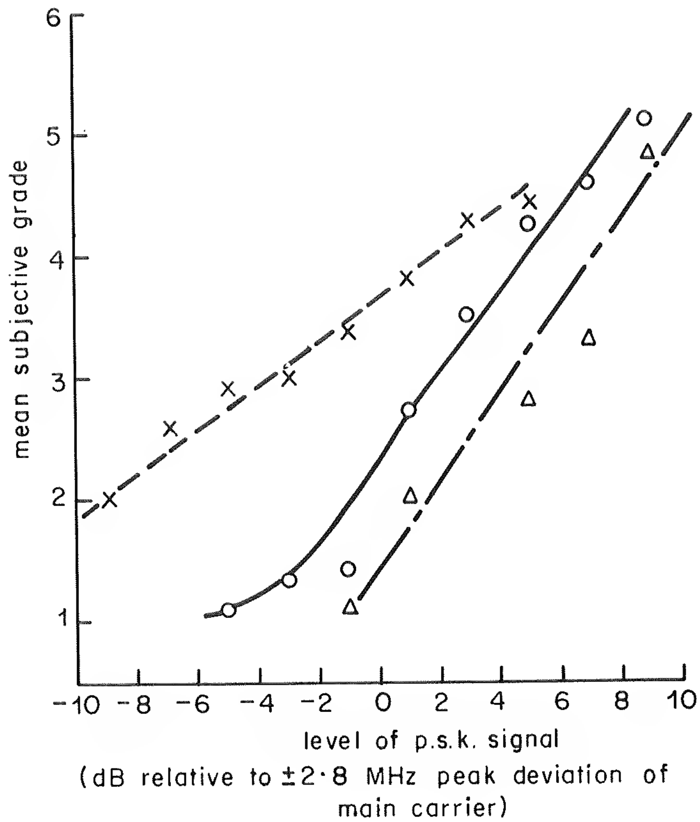

Fig. 2 - Results of subjective tests using a p.s.k. sound signal in addition to a f.m. subcarrier sound signal

O——O——O Results for colour bars as picture, and modulated p.s.k. signal

X— —X— —X Results for colour bars, and unmodulated p.s.k. signal

Δ— - Δ— - Δ Results for slide picture, and modulated p.s.k. signal

It has already been mentioned, in Section 2, that spectral shaping of the p.s.k. signal is likely to be performed by two filters, one at the transmitter and one in the receiver. Each filter would then contribute a proportion of the shaping. As explained earlier, for all the tests so far described only one filter was available and this was placed in the p.s.k. signal path before the sound and vision signals were combined, i.e. at the transmitter. A brief test was therefore conducted with the filter removed, in order to assess its effect. The test showed that it was necessary, in the absence of the filter, to reduce the injection level of the p.s.k. signal by 2 dB to restore picture quality, but theoretical considerations indicate that noise in the p.s.k. channel would be reduced by 2 dB, relative to the condition with filtering only at the transmitter, if the filter were incorporated entirely in the receiver. This implies that a system in which the p.s.k. filtering was to be shared between the transmitter and the receiver would require the p.s.k. subcarrier to be at a level of about −2 dB relative to ±2·8 MHz deviation. At this level, a p.s.k. sound system would be perfectly feasible.

* The observers assessed impairment of the picture according to the 6-point impairment scale given in CCIR Report 405-1 (New Delhi, 1970). The scale is as follows:

1. Imperceptible
2. Just perceptible
3. Definitely perceptible, but not disturbing
4. Somewhat objectionable
5. Definitely objectionable
6. Unusable

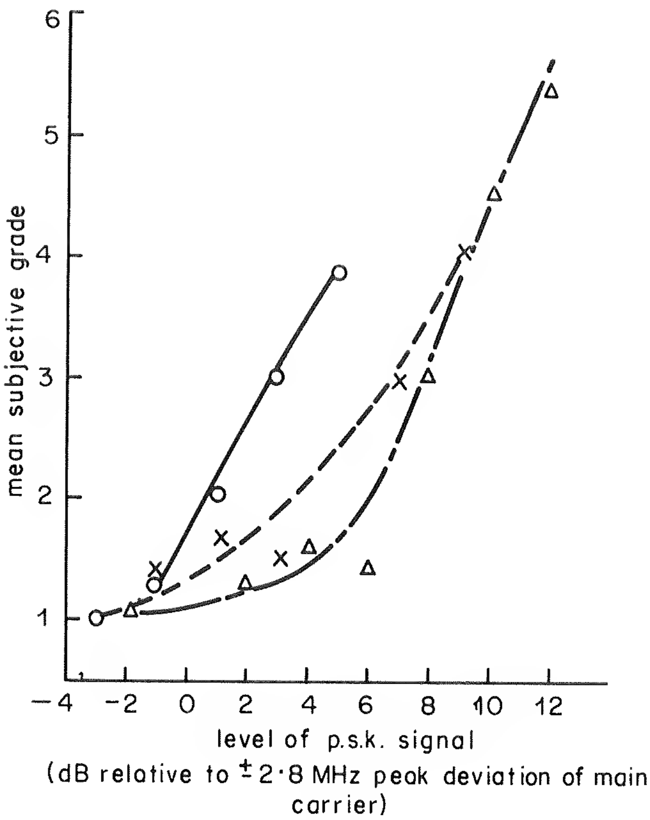

Fig. 3 - Results of subjective tests using p.s.k. subcarrier sound signal (without a f.m. subcarrier sound signal)

O——O—— Results for colour bars as picture, and modulated p.s.k. signal

X— —X— - Results for colour bars, and unmodulated p.s.k. signal

Δ——·Δ—— Results for slide picture, and modulated p.s.k. signal

4. Conclusions

A four-phase p.s.k. subcarrier sound signal could replace the proposed f.m. sound signal, and provide two independent high-quality sound channels for a satellite f.m. television transmission. The sound channels so provided would offer a better signal-to-noise ratio than that offered by a sound channel provided by a f.m. subcarrier, particularly at the limit of the service area. The p.s.k. subcarrier should have a frequency of 5·9996 MHz ± 400 Hz and it is recommended that it should deviate the main carrier by ±2·22 MHz peak.

It is very unlikely that a four-phase p.s.k. subcarrier sound service could be provided on a satellite f.m. television signal in addition to the f.m. subcarrier sound already proposed without detriment to the picture. Which would suffer more, the picture or the f.m. sound channel, would depend upon the level at which the f.m. subcarrier were added to the video signal before modulation.

5. References

1. CCIR: Recommendation 405-1, XIIth Plenary Assembly (New Delhi, 1970), Vol. VI, Part I, p. 148, Curve B (625 lines).

2. GILCHRIST, N.H.C. 1973. Satellite broadcasting: bandwidth requirements for f.m. television signals. BBC Research Department Report No. 1973/19.

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